Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 147 (2016) 175 – 180

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

Modelling the interaction between racehorse limb and race surface

Jennifer Symons[ab], David Hawkins[ac], David Fyhrie[ad], Shrinivasa Upadhyaya[e], Susan Stover[ab]*

[a]Biomedical Engineering Graduate Group, [b]Department of Anatomy, Physiology and Cell Biology, School of Veterinary Medicine,
[c]Department of Neurobiology, Physiology and Behavior, [d]Department of Orthopaedic Surgery, UC Davis Medical Center,
[e]Department of Biological and Agricultural Engineering
University of California, Davis Davis, CA 95616 USA

Abstract

Musculoskeletal injuries are the leading cause of racehorse fatalities and attrition. Race surface mechanics affect racehorse limb biomechanics, and therefore can affect musculoskeletal injuries. Installation of experimental race surfaces to determine their effect on racehorse limb kinematics is not financially feasible. Furthermore, field data collection is time consuming, labor intensive, and requires the use of live animals. Computational modelling provides an economical option to survey a wide range of surface mechanics and resulting effects on racehorse limb motions. This research aimed to develop and evaluate an integrated racehorse limb and race surface computational model. The interaction of a virtual galloping racehorse impacting virtual race surfaces was modelled in SIMM using combined forward/inverse dynamics. In vivo kinematic data were averaged to determine proximal forelimb, trunk, and hindlimb kinematic model profiles throughout gallop stance, as well as distal forelimb initial conditions. All distal forelimb joints and hoof translations were free to respond to external forces applied by the race surface model during stance. Race surface model coefficients were determined from previously measured race surface mechanics and forward dynamic simulations of a track-testing device. Simulation results were compared to distal forelimb motions of actual galloping racehorses on mechanically measured race surfaces. Model predicted kinematic profiles (metacarpophalangeal angle and hoof translations) had qualitative shapes and peak magnitudes within ranges of experimental data. Simulated peak metacarpophalangeal angle and hoof translations were within 11 degrees and 4 cm respectively. Future model applications include estimation of the effects of variation in race surface parameters on racehorse limb biomechanics.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of ISEA 2016

Keywords: race surface; horse; modeling; dynamics

1. Introduction

Musculoskeletal injury is the leading cause of racehorse fatalities and attrition. The forelimb fetlock or metacarpophalangeal joint is the most prevalent site of injury, with the suspensory apparatus being the most commonly affected structure. The leading veterinary hypothesis suggests that observed fetlock pathologies, including those in the suspensory apparatus, are consistent with extreme angles of fetlock hyperextension, or dorsiflexion[1-3]. Previous research has linked the degree of fetlock hyperextension to the magnitude of vertical forces applied to the hoof and limb during stance[4]. Thus, mechanisms to alter ground reaction forces applied to the hoof have the potential to modulate fetlock hyperextension during stance, and associated propensity for injury.

Although racehorse musculoskeletal injuries are a function of many factors, including training frequency and intensity, race surface design is an attractive avenue for injury prevention. Race surface mechanics are a function of many controllable factors, including material composition[5], moisture content, temperature[6], and maintenance procedures[7, 8]. However, the relationship between these contributing factors and resulting surface mechanics is complex and poorly understood. Attempts to

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000.
E-mail address: author@institute.xxx

1877-7058 © 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.209

alter race surface mechanics have met resistance in the industry. Roughly one decade ago, synthetic surfaces, that were designed to reduce the concussion of the hoof colliding with the surface, replaced many traditional dirt surfaces. Although a decrease in musculoskeletal fatalities coincided with the change in surfaces[9], management of the surfaces proved to be difficult. Trainers and veterinarians within the industry observed longer race times and more non-catastrophic musculoskeletal injuries that prevented horses from training and competing. These negative perceptions ultimately led to the reinstallation of dirt surfaces. Application of quantitative methods and engineering design principles may contribute to optimization of race surfaces for equine musculoskeletal health.

Computational models provide an economical solution to study parameters that may be difficult to measure experimentally. Race surface installations are expensive, upwards of $8 million. Thus, experimental installation of race surfaces is not feasible. Furthermore, experimental data collection on actual racehorses is difficult, time consuming, and necessitates the use of animals in research. Conversely, computational modelling facilitates surveying a wide range of race surface mechanical properties to gain insight into the effects on racehorse limb motions and musculoskeletal tissue loads that are difficult to measure in vivo. Previous research studies have developed an equine forelimb musculoskeletal model[10], as well as a race surface mechanical model[11]. This study aimed to integrate these two models in a series of combined forward/inverse dynamic simulations, and to verify the integrated model by comparing simulated distal lead forelimb motions during stance to kinematic data collected from actual galloping racehorses[12].

Nomenclature

z	Vertical displacement
$\dot{z}$	Vertical velocity
F_n	Normal force
C_s, C_d	Cushion race surface parameters
P_{ds}, P_{de}, P_{vs}, P_{ved}, P_{vev}	Pad race surface parameters
F_h	Horizontal force
H_o, H_s	Horizontal race surface parameters

2. Methods

Combined forward/inverse dynamics of lead forelimb gallop stance were simulated on virtual representations of measured race surfaces, and compared to lead forelimb kinematics of actual galloping racehorses.

2.1. Animal subjects

Five Thoroughbred racehorses (3 ± 1 years, (mean ± SD); 3 females, 2 castrated males; 439-541 kg) were studied with owner consent. All subjects were evaluated for lameness and deemed sound for the Institutional Animal Care and Use Committee approved study protocol. Horses were conditioned for another study with padded shoes on their forelimbs, as well as an on-board computer saddle; both remained present throughout kinematic data collection. All hindlimbs remained unshod.

2.2. Experimental data

Two-dimensional (sagittal plane) racehorse trunk and limb motions[12] were quantified by high-speed kinematic video (500 Hz) at 2 racetracks with differing race surfaces, one dirt and one synthetic. The dirt surface (83% sand, 10% silt, 7% clay) was harrowed 8.3-8.9 cm deep. The synthetic surface (proprietary wax-coated blend, 80% sand) was harrowed 5 cm deep. Race surface vertical and horizontal mechanics[5] were measured by a track-testing device (force and displacement, 2000 Hz), designed to mimic the effective mass, cross-sectional area and speed of a racehorse's hoof impacting the ground, and a shear vane tester with normal force and torque load cells, respectively. Track-testing device impacts (n=173) were performed on freshly harrowed patches of race surface, as well as consolidated patches to determine the effect of maintenance on race surface mechanics.

2.3. Musculoskeletal model segments

An existing equine forelimb musculoskeletal model[10] was further developed to better approximate the mass and mass distribution of a racehorse (Figure 1). The right forelimb was modeled to reflect bone, ligament, tendon, and muscle anatomy from transverse slices of MR/CT data (hoof to elbow). Racehorses' forelimbs are coupled to the trunk by a series of sling muscles; this linkage was modeled as a damped spring between the radius and trunk with a pin joint allowing for rotation between segments. The distal third of the humerus was included to provide accurate muscle-tendon unit origins and paths crossing the elbow. The remainder of the horse's mass was modeled by a series of ellipsoids (head, neck, trunk, pelvis, femora,

Download English Version:

https://daneshyari.com/en/article/853377

Download Persian Version:

https://daneshyari.com/article/853377

Daneshyari.com